CARPARK – A Low-Cost, Implementable Smart Parking Solution for University Campuses

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ABSTRACT

There is a current, recurring problem on UCT campuses whereby staff and students spend their time and money searching for parking until they find a parking lot that can accommodate them. With CARPARK, I aim to provide a fully implementable and viable smart parking solution, which will be integrated into the current infrastructure. The system will deliver real-time parking information to all drivers through a display board and an accompanying app. In this paper, I analyse previous work done on the topic, both the strengths and weaknesses, in order to begin formulating the new parking system, incorporating previous work, whilst ensuring it maintains its promise of being low-cost and durable. While it may not solve the problem ultimately, it is a much-needed step in the right direction that UCT staff, students and guests have called out for in years gone by.

KEY TOPICS

Smart Parking; Internet of Things; Arduino; Human-Computer Interaction; Databases; Application Design

1. INTRODUCTION

While students and staff at the University of Cape Town are granted access to legally park on campuses by purchasing a UCT parking disc, it is not always guaranteed that they will find a parking lot that has a space available for them. For most, this is a daily concern, resulting in having to plan their day around this inevitability. This hinderance has more implications than what meets the eye, such as the environmental effect it can have. While space may not be available, these parking seekers expense unnecessary fuel in the search for a parking space, which is detrimental to both the atmosphere as well as their monthly fuel expenditure.

Moreso, the continuous search for available parking leads to congestion in both parking areas and by extension, the roads and lanes leading up to them, creating an exponential effect. Part of the problem is that the parkers do not have complete information on the status of the parking lots, which according to a paper published years back, in 1993, whereby the supply of as much parking information to drivers has positive effect, as it allows them to make their own driving and parking suggestions.

The motivation therefore for this paper and the eventual project is to address the current parking problem on campuses by introducing a smart parking system whereby the information and availability of parking lots on campuses is available to both staff and students as well as the monitoring teams behind the parking lots, such as UCT Traffic. The goal of the final physical project is for there to be an easily implementable and low-cost option for UCT to implement that will also be scalable, to ensure that as many of the UCT controlled parking areas are able to be accommodated and implemented into a more rounded and monitorable parking system.

As aforementioned, beside for reliability, one of the main goals is to ensure that this is a low-cost solution and in order to accomplish this, we have decided to opt for using the Arduino platform as our basis. By using this platform, there are many various types of sensors and thus, different approaches to solving the problem. The reason for this specific choice is explored later on in this literature review.

2. FINDINGS

In this section, I aim to highlight some of the work that has been done by both professionals and academics in the field in the past. By the end of the section, it may become clear as to where the gap in the market is and this will be dealt further in the discussion and analysis section.

2.1 Crowdsourced Data

The first paper in which there is content relating to the problem that we face at UCT is titled *ParkJam*. In here, the author explores the use of a crowdsourcing solution to the parking problem that was faced at the Milton Keynes campus for The Open University in the United Kingdom. What this entailed is the provision of information to students and staff by way of an in-house developed application and would rely on all parkers on the campus to submit information about their parking. What they did not foresee in the development and planning of the application is the requirement that either all users would have to be active or there would have to be a set of users who are highly active, in the sense that they would submit parking information on behalf of their colleagues. This led to an ultimately unsuccessful solution as the system relied on the user's inputs and failed to address the real needs of the users.

2.2 Individual Sensors

The next paper to explore concerns the introduction of sensors in conjunction with a set of hardware in order to create a smart parking system, this paper titled *IoT Based Smart Parking System*. The author of this paper looked at introducing a central monitoring system with the use of a Raspberry Pi, and attached to this central module would be Passive Infrared Sensors which detect the presence of vehicles in a specific parking space, using light shifting. An Android application is also proposed for commercial purposes whereby drivers are able to reserve a parking spot for themselves, where the spot will be displayed as taken to other drivers, as well as having the option of paying for their parking, via the app. The solution that was developed was not implemented, it was more a of a proof-of-concept solution.

2.3 Exploratory Use of a Central Server

The next paper to consider explores the use of a central server whereby all information pertaining to a single parking space in a parking lot is transmitted to a central, web-based server. This is an extension from the previous paper. This information then uses the geolocation that is provided by the driver's Android app that will determine which best and closest parking lot to go to and then navigates them towards that parking lot. This then would be a fully encompassed system and was proposed for use in a University system in order to prove it's use case in a broader city-wide parking system.

2.4 Sensors at Entry/Exit Points

The final paper in which to exam considers more of the low-cost hardware and easily implementation that this paper is aiming to achieve, and it is aptly titled *Intelligent Parking Lot Application Using Wireless Sensor Networks*. In this exploration, the authors compare the performance of magnetonic sensors, namely those that detect a change in magnetic field for a presence of a moving vehicle, with ultrasonic sensors, which transmits a sound wave at a frequency of 40Hz as well as receiving the echo. Both of these sensors are able to thus detect the presence and movement of vehicles and they propose this as a solution for detecting the entering and exiting of cars from a parking lot, with mention specifically to University campuses, however they argue that the detection algorithm would have to be accurate. It is also mentioned that this information on availability could and should be presented to potential parkers, however do not make any suggestion of how this should be done.

3. DISCUSSION/ANALYSIS

In order to determine whether there is a viable solution that could be developed that would both be implementable, as is the goal of this paper, but would also be original, we would need to address the finding from previous research papers and implementations of this technology.

In this section, I will split up into several subsections depicting some of the issues and concerns that should be addressed based on the previous findings section.

3.1 Core Controller

In the papers presented above, as well as additional ones which were consulted, where there is a general system that has hardware involved, there is generally a microcontroller or single-board-based computer that is able to control all the moving parts of a system. These can range from various Raspberry Pi models to the more expansive and open-source Arduino boards. There are several reasons as to why these are selected by the people who designed the system as well as other Do-It-Yourself practitioners, namely:

1. Price – All of these boards are relatively cheap, compared to a fully-fledged computer implementation
2. Performance – While they may be relatively cheap, the manufacturers of these boards ensure they are able to perform many tasks with relatively powerful hardware. In addition to this, the system that these boards run are not technologically intensive enough to require a more powerful machine and so, the performance to price ratio is struck just right.
3. Portability and Size – In contrast to larger computer systems, these boards are tiny, less than the size of a human hand. The sheer size of these boards allows for them to be moved around easily as well as installed and implemented virtually anywhere, without compromising much space.
4. Reliability – Both of these types of boards are incredibly reliable, with extensive testing being done on both of them. With regards to the Raspberry Pi, this is proprietary hardware and so they put all measure in place to ensure that the boards are up to standards.

   With regards to the Arduino boards, the designers of these boards, a group of Italian engineers, decided to make the plans open-source, so that anyone had access to the blueprint of the system. By doing so, they welcomed a community of engineers and developers to modify.

It would then make sense that a proposed solution would use one of these technologies. From a purely engineering perspective, only the Arduino would be required as there is unnecessary extra computational capabilities that go into the Raspberry Pi, such as it's Graphical capabilities, which makes it comparatively more expensive.

3.2 Sensor and Presence Detection

As has been discussed in the papers, several sensors have been used in conjunction with the controllers. Namely, these were the Passive Infrared sensors, the Magnetonic sensors and the Ultrasonic sensors. What all of these sensors offer are an incredibly cheap detection method, while ensuring that they are reliable. However, there are disadvantages to all of the sensors, which can be listed below:

- Infrared – Despite the passive detection being able to operate on objects that it encounters within it's field of view, it is incredibly susceptible to bad weather conditions. The solution that is to be implemented at UCT would need to be able to withstand all weather conditions as it will be stationed at the entrance to the parking lots on campus which are all outside. In addition to this, it is only able to determine the presence of a vehicle and so to distinguish between an entering or exiting vehicle would not be possible.
- Magnetonic or Piezoelectric – This type of sensor is well rounded however it's primary disadvantage appears when it detects the magnetic field of more than one object in sequence, whether this be 2 vehicles or alternative objects that give off an electromagnetic frequency and so there would be a chance for interference.
- Ultrasonic – The biggest deterrence to the use of this sensor is that it has a very limited field-of-view or range to which it can transmit its signal, and so any implementation that uses this sensor would have to take that into account. A minor issue has been noted that it may be susceptible to drastic weather.

Taking into account all of the aforementioned disadvantages to each of the sensors, there is no clear winner as they all have their own use cases. Any solution that aims to be all encompassing and able to handle all conditions would have to explore using sensors in conjunction with each other and to possibly explore all the other kinds of sensors that are available to the microcontroller platforms.

3.3 Centralised Server

As is evidenced in a couple of the referenced papers, there is a certain benefit to storing data in a centralized server. By doing so, the system allows for real-time monitoring by provided services]es that would regularly monitor those areas. It also gives them a closer and more in depth understanding of what is happening in the specified parking space.

With the introduction of a server, this allows for several extensible functionality to enhance the user's experience. As logs would be submitted to the server's database when a car is detected to be entering or exiting, these logs could be displayed for whoever requires them. Moreso on this availability of information and data, statistical models could be formulated in order to engage with the raw data even more and understand, at least statistically, the behaviour of the users in the system.

By having a centralised server, as previously referenced solutions have done, it is possible to port the necessary information to an application which potential parkers would be able to use. A further discussion takes place in the following section

3.4 Android Application

As briefly introduced in the previous section, the integration of an application is certainly possible with the data that is sent to the server. Users then have the ability to view the information that is relevant to them when they decide to do so.

However, the responses to apps are varied, such as is evidenced in the paper where some apps are found to help the user experience, while others fail to address the true needs of the user. What can be said about this is that any app that is developed for the user, needs to have the user experience in mind primarily, with the functionality a supplementary consideration. Without users, the app would be rendered useless, hence the reasoning behind this rationale.

When taking into account the design of an app for users, work needs to go into ensuring that it is compliant with the standards set up by the field pertaining to Human-Computer Interaction. By doing so, the app focuses on the User's Experience, which only encourages the adoption of the app by users.

3.5 Powering of Devices

As most of these research papers were ideas and not necessarily implementations of a system or solution, not much is spoken about technically in terms of what specific hardware and design schemas are used and one consideration is as to how the devices are all powered. As a single paper suggests what can be done is instead of powering the microcontrollers and any of the potential devices with a simple DC power supply, there is potentially a scope to use renewable sources of power to do so. What the author suggests is using a the natural energy from the sun in order to power a battery with the use of solar panels, which will then supply all the power needed to the system.

By having a power source such as this further emphasizes the portability and thus the implementability of any proposed system.

4. CONCLUSIONS AND FUTURE WORK

This section offers some closing thoughts based on the findings section and the further discussions on the successes and failures of the previous work done in the field. There is then a final subsection that outlines some of the potential further enhancements to the solution that will create an all round better system.

4.1 Conclusions

After having reviewed several pieces of literature on the topic of a smart parking system, it is clear that there is a universal need for solutions. However, one of the problems associated with this is the fact that there will be no single solution that serves as the gold standard for a smart parking system because each system requires its own customized solution.

In the case of UCT, there is already an infrastructure in place for the parking system, albeit arguably a lacklustre one, and to overhaul this completely with a brand-new parking system would most likely not work and if it were to, would be a project that would take several years to complete. What UCT does need before any of that happens is a temporary solution to the parking problem, whether that be a monitoring system or slight tweaks to how parking is operated.

One of the biggest concerns with regards to smart parking solutions is how much they cost to implement, and this is still the case for some of the solutions that I referenced to. While some of these solutions use the same set of tools as I will be using, there is a physical hardware component which I will have to build myself, considering the cost among several factors. Along with ensuring that the physical components work, I will need to conduct several tests on the hardware and specifically the implementation on it in order to avoid potential issues, such as weather or theft. The final product needs to be a durable and scalable item.

From the software perspective, I will be able to use the same code libraries from which they based their code off of, with slight modifications in order to cater to the requirements for a specific UCT implementation.

4.2 Future Work

Potential future work could look at exploring alternative ways to charge for the ability to park on campus, such as a 'pay-as-you-park' methodology, where you would only pay for however often you park for in a certain area. This could be implemented by introducing one of two technological extensions onto a smart parking monitoring system that would be proposed:

1. RFID Tags on Parking Discs – The current parking discs that are given to staff and students could be embedded with Radio Frequency Identification tags which would then be triggered at the entrance and exit to parking areas. By doing so, an account could be opened up with UCT traffic whereby at the end of the year, the amount to be paid by the staff member or student takes place, either manually or automatically.

2. License Plate Detection – While this would be a much more challenging introduction, there are already systems that do this, such as the speed cameras on South African roads. In its simplicity, there would be a high definition

camera that takes a picture when a car is entering or exiting the parking lot. It would then upload this image to the central server, whereby a Neural Network identifies the pixels in the picture that contain the number plate and then Optical Character Recognition software is applied to get the raw text of the number plate. This would then be matched up with the UCT Traffic's pre-existing database of staff and students with valid parking discs.

While the individual aspects of the solution that will be proposed are not revolutionary, I believe that the amalgamation of all of the processes from these technologies will be an innovative success, especially in a UCT context. It will be a low-cost solution, while maintaining its scalability to allow it to be implemented in every parking lot on campus. The accompanying smartphone app will then give the user's the information on parking in the area that they have lacked and can now make informed parking decisions.

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